SUCCESSFUL RESECTION OF FUSIFORM ANEURYSM OF AORTIC ARCH WITH REPLACEMENT BY HOMOGRAFT

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Reprint from
SURGERY, *Gynecology & Obstetrics*
DECEMBER, 1957
VOLUME 105, 657–664

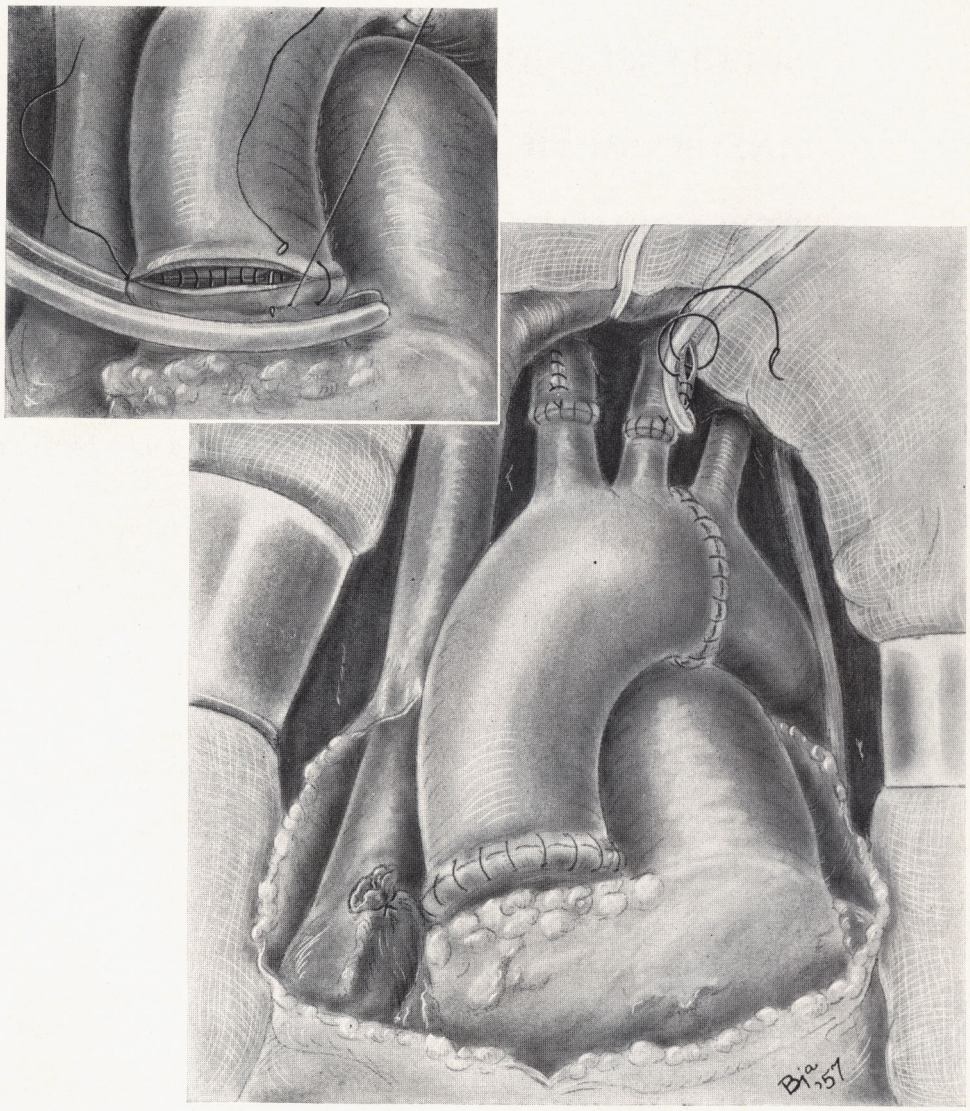

FIG. 7. Drawing showing in inset final anastomosis of homograft to base of ascending aorta. After completion of all anastomoses to homograft, all occluding clamps are released restoring normal circulation. Perfusion catheters are removed, and the arteriotomies for this purpose in innominate and carotid arteries are repaired by lateral arteriorrhaphy.

Successful Resection of Fusiform Aneurysm of Aortic Arch with Replacement by Homograft.—Michael E. De Bakey, E. Stanley Crawford, Denton A. Cooley, and George C. Morris, Jr.

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TREATMENT OF AORTIC ANEURYSMS by resection with restoration of continuity by aortorrhaphy or graft replacement has now become well established. Limiting factors to successful application of this method have been concerned primarily with the nature and location of the lesion and with the necessity for temporary arrest of aortic circulation during performance of the procedure. For aneurysms located distal to the left common carotid artery these factors have been satisfactorily overcome by use of hypothermia and the temporary shunt. For aneurysms proximal to this level, however, they have constituted much more difficult and hazardous problems. For one thing, arrest of circulation at this level interrupts cerebral blood flow which, even after a few minutes, can result in fatal ischemic damage to the central nervous system. Also, occlusion of the ascending aorta rapidly imposes such a serious strain upon the left ventricle that acute cardiac failure may ensue.

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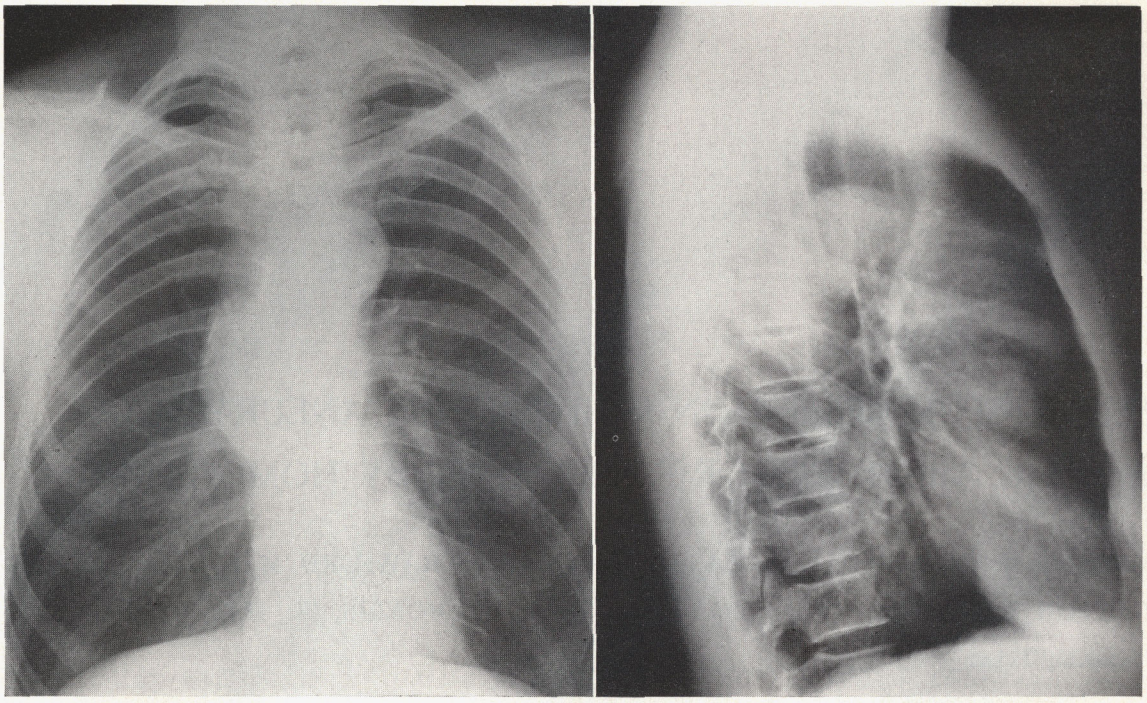
Efforts to solve these problems were directed first toward use of temporary shunts which would permit maintenance of circulation during exclusion of the aortic arch. On the basis of their experimental studies in which multiple, small-bore, polyethylene tubes were employed for this purpose, Schafer and Hardin used this method on a patient whose aortic arch was resected, but the patient died in the operating room. A somewhat similar attempt was made by Stranahan and associates, who utilized a larger bore shunt 10 millimeters in diameter from ascending to descending aorta with one limb of the shunt to the innominate artery. Although the patient survived the operation, he died shortly after completion of the procedure. Significantly, there were manifestations of right hemiplegia, suggesting cerebral damage from failure to provide circulation through the left common carotid artery.

We previously reported the use of the temporary shunt principle for resection of aneurysms of the aortic arch in 3 patients (1, 3). The shunts, made of polyvinyl sponge



a b

FIG. 1. a, Posterior anterior roentgenogram of chest showing aneurysm arising in ascending aorta, the right lateral margin of which is outlined by flecks of calcium; b, lateral projection suggests involvement of transverse arch.

(ivalon) with an internal diameter of 14 millimeters in the first 2 cases and 20 millimeters in the third case, were anastomosed end-to-side to the ascending and descending aorta and to both the innominate and left common carotid arteries. Despite use of hypothermia and the shunt, the first patient died on the sixth postoperative day of cerebral damage from temporary ischemia resulting from thrombosis of the right carotid shunt. Both hypothermia and the shunt procedure were also employed in the second case. Although this patient regained consciousness within 30 minutes after completion of the operation and appeared to be progressing satisfactorily, respiratory difficulties subsequently developed which presumably led to his death 6 hours later. In the third case only the shunt was employed. The immediate postoperative course seemed satisfactory, as evidenced by the fact that by the ninth postoperative day he was ambulatory and taking a regular diet. Unfortunately, a mediastinal infection developed which led to his death 2 days later. Despite the fact that none of these patients ultimately survived, owing to development of tragic complications, this experience demonstrated the technical feasibility of the procedure. The method has, however, certain disadvantages. For one thing, the necessity of performing and later removing the 4 end-to-side anastomoses of the shunt prolongs operative time, which in some of these patients may increase the operative risk. For another, it may not be possible to apply the shunt in cases in which the aneurysm arises quite proximally on the ascending aorta. Under these circumstances, the length of ascending aorta proximal to the aneurysm is insufficient to permit attachment of the shunt.

For these reasons consideration was given to the use of temporary cardiac bypass with the artificial heart-lung apparatus. After the feasibility of this method had been demon-

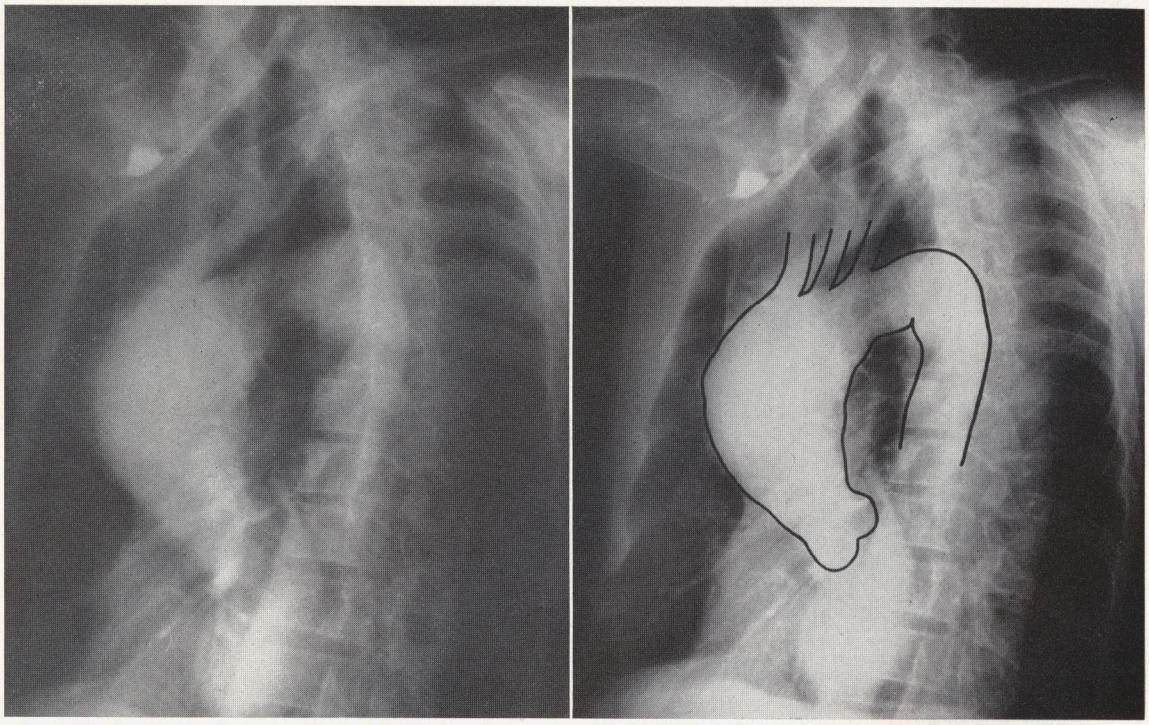


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FIG. 2. a, Angiocardiogram with, b, superimposed outline showing fusiform aneurysm involving ascending aorta and transverse arch.

strated experimentally, temporary cardiac bypass was employed successfully in a patient with an aneurysm involving the entire ascending aorta, which was resected and replaced with a homograft (2). It is now a little over 1 year since this operation was performed, and the patient is well and has resumed normal activities. The successful application of this procedure led us to the belief that it provides a better method of resecting aneurysms of the aortic arch. This conviction has been strengthened by its successful application for this purpose in another patient whose aneurysm involved both the ascending aorta and transverse arch as illustrated in the following case report.

CASE REPORT

B. M., a 56 year old white man, was admitted to the Methodist Hospital, Houston, Texas, March 12, 1957, because of pain in the left side of the chest of 1 year's duration. Nine years previously the patient received multiple injections of penicillin because of a positive reaction to the serologic test for syphilis. Following this therapy the patient remained well and worked as a carpenter until 1 year before admission when he developed pain in the left side of the chest. Roentgenographic examination of the chest then revealed the presence of an aneurysm in the thoracic aorta, and since subsequent examinations showed progressive enlargement of the aneurysm, the patient was referred for surgical therapy.

Physical examination on admission to the hospital was essentially normal. Blood pressure was 122 millimeters of mercury systolic and 70 millimeters of mercury diastolic, and the pulse was regular. Results of electrocardiography and routine examinations of the blood and urine, including serologic tests for syphilis, were normal. Roentgenographic examination of the chest revealed an aneurysm in the region of the aortic arch (Fig. 1). A thoracic aortogram performed March 14, 1957 showed a moderate sized fusiform aneurysm involving the ascending and transverse segments of the aortic arch including the origins of the innominate and left common carotid arteries (Fig. 2).

On March 21, 1957, operation was performed under general anesthesia. With the patient in the supine position, both thoracic cavities were opened through an anterior incision made across the sternum and into both third intercostal spaces (Fig. 3). After the

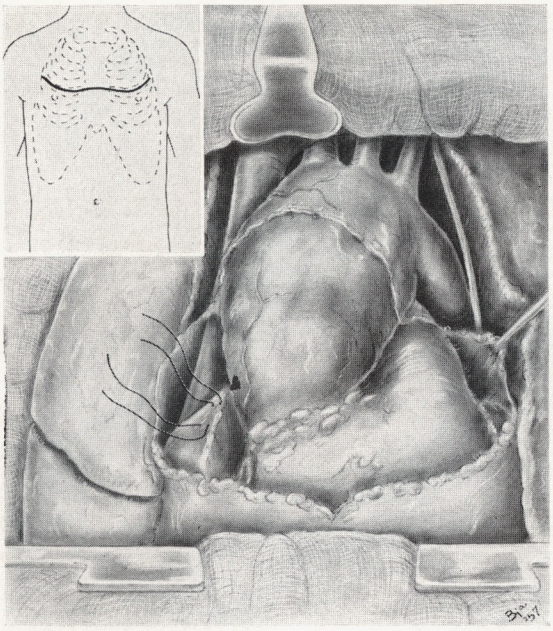

FIG. 3.

FIG. 3. Drawing made at operation showing technique employed in resection of aneurysm. Inset shows incision used through anterior third intercostal spaces with transection of sternum. After opening pericardium and freeing mediastinal structures from aortic arch and its branches, the fusiform aneurysm is visualized arising from base of ascending aorta to origin of left subclavian artery.

FIG. 4. Diagram showing method of exclusion of aortic arch using extracorporeal circulation.

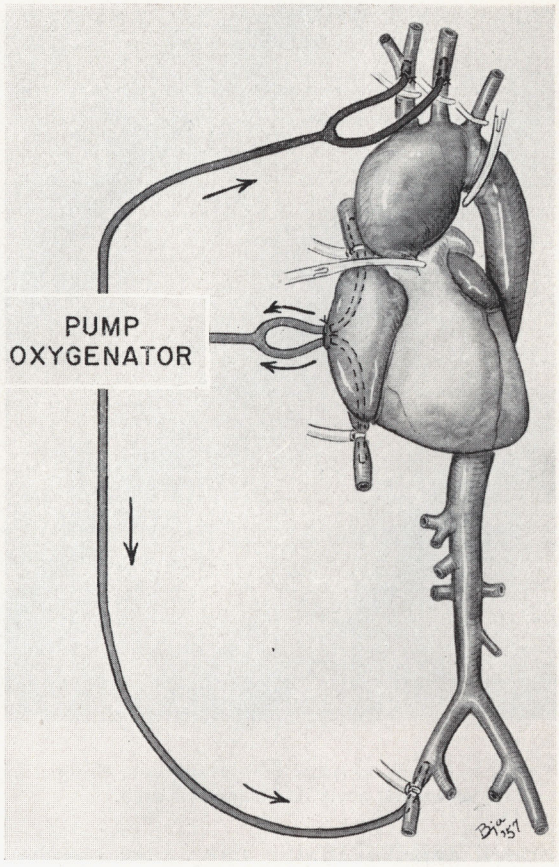

FIG. 4.

mediastinum was separated from the anterior chest wall, the base of the heart and upper mediastinum were well exposed by retraction of the chest wall on each side with rib spreaders. The aneurysm was fusiform and involved a segment of the aorta that began 4 centimeters beyond the base of the heart and extended to the origin of the left subclavian artery (Fig. 3). Although the descending segment of the aortic arch was elongated and kinked, the diameter of the lumen in this region was essentially normal. The entire aortic arch and its branches were completely exposed by opening the pericardium and dissecting this structure, together with other mediastinal tissues including the pulmonary artery, from these vessels. After completely mobilizing the aortic arch, the aorta, both proximal and distal to the aneurysm, and the major aortic branches were encircled with umbilical tapes for traction during application of clamps.

An artificial heart-lung apparatus using a modified DeWall-Lillehei oxygenator was primed with 6 units of heparinized blood. The superior and inferior venae cavae were mobilized within the pericardial cavity and encircled with umbilical tapes to be used later as temporary tourniquets. After the patient had been given 100 milligrams of heparin, a No. 16 tygon catheter was inserted into each vena cava through a small incision made in the right auricular appendage and secured in place by pursestring sutures. A similar catheter was inserted into the common iliac artery through an arteriotomy made in the right common femoral artery, and 2 smaller catheters were inserted into the innominate and left common carotid arteries, respectively, through small arteriotomies made distal to the aneurysm in the thoracic segments of these vessels. These 2 catheters only partially filled the lumen of these arteries and were held in place by small pursestring sutures surrounding the arteriotomies. Cerebral circulation was thus maintained at all times.

The venae cavae were occluded around the catheters in these vessels, and the total cardiac inflow was diverted into the oxygenator, from which oxygenated blood was pumped into the right common iliac, innominate, and left common carotid arteries. The rate of blood flow into the iliac artery was 2,100 cubic centimeters per minute, and into each of the in-

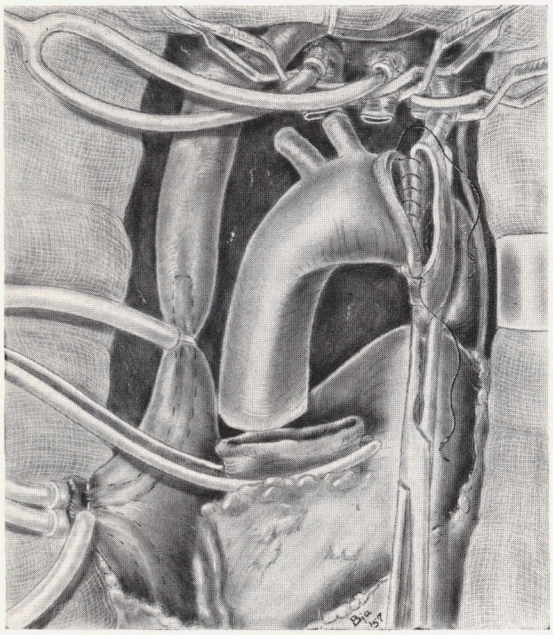

FIG. 5. Drawing showing replacement of aortic arch following its excision with anastomosis of homograft to distal aortic opening using continuous suture of No. 000 arterial silk.

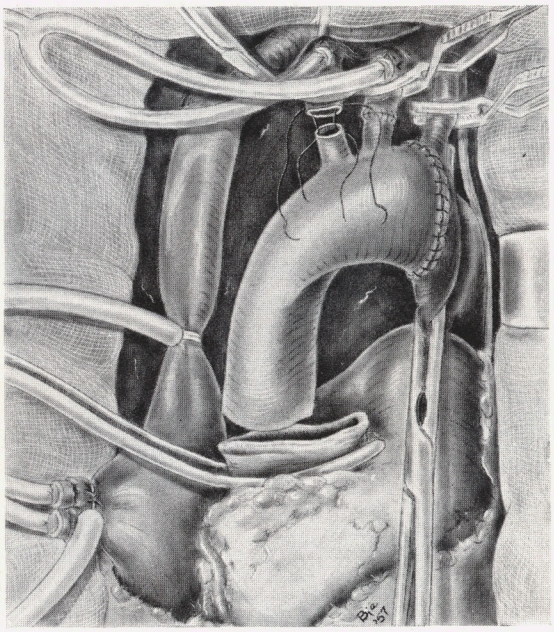

FIG. 6. Anastomoses of homograft to distal aortic opening and to left common carotid artery have been completed, and the next anastomosis to innominate artery is being performed.

nominate and left common carotid arteries it was 250 cubic centimeters per minute. Distal perfusion was assured in the last two arteries by application of temporary occluding clamps between the arteriotomies and the aneurysm during the time of perfusion. A temporary occluding clamp was also placed across the left subclavian artery just distal to its origin. The aorta was then cross-clamped approximately 4 centimeters distal to the origin of the coronary arteries and immediately beyond the origin of the left subclavian artery (Fig. 4).

The aortic arch containing the aneurysm was then excised and replaced by a reconstituted lyophilized aortic arch homograft, care having been taken to preserve the vagus, recurrent laryngeal, and phrenic nerves. The graft was inserted by anastomosis of the distal aorta and then the left common carotid, innominate, and proximal aorta in that order, using continuous over-and-over through-and-through sutures of No. 000 silk (Figs. 5 to 8). At the completion of the anastomoses 150 milligrams of protamine sulfate was given, and the bulldog clamps, which had previously been placed on the innominate, left common carotid and subclavian arteries, were removed after which the distal and proximal aortic clamps were removed in that order. The tourniquets occluding the venae cavae were immediately released, the pump discontinued, and normal circulation was restored through the heart and lungs. The entire perfusion time was 43 minutes. The operation was completed by removing the perfusion catheters, repairing the mediastinum, and closing the chest wall. Catheters were inserted into each thoracic cavity for drainage. Pathologic examination of the specimen removed at operation showed the characteristic findings of a fusiform aneurysm of the ascending aorta and transverse arch, probably of syphilitic origin (Fig. 9).

Immediately after the operation, the patient responded to questions and moved all extremities. Recovery was essentially uneventful, and the patient was discharged from the hospital 16 days after the operation. He has since been observed several times and at this writing, 5 months postoperatively, his condition continues to be satisfactory and he has resumed working full time as a carpenter. Roentgenograms of the chest made at his last follow-up examination approximately 5 months after operation revealed essentially normal findings (Fig. 10).

DISCUSSION

The limiting factors to the successful application of resection of aneurysms of the proximal portion of the aortic arch suggested the need for a better method to solve the problem and led to consideration of the concept of extracorporeal circulation for

FIG. 8. Photograph at operation showing homograft replacing ascending aorta and transverse arch including branches to innominate and carotid arteries.

this purpose, particularly in light of increasing experience demonstrating its successful employment in the treatment of intracardiac lesions. Accordingly, experiments were conducted in which an artificial heart-lung apparatus with a modified DeWall-Lillehei bubble diffusion oxygenator was used. With total cardiopulmonary bypass being provided by this means and use of flow rates of approximately 35 cubic centimeters per kilogram of body weight, it was found that circulation through the aortic arch could be arrested for periods up to 1 hour without serious cardiac or neurologic disturbances. Of particular importance was the fact that cardiac function was maintained in a relatively normal manner but obviously with reduced cardiac output during the period of occlusion of the aortic arch. With pulmonary ventilation also being maintained during this time, presumably the blood that remains in the cardiopulmonary system after total inflow occlusion provides adequate circulation to maintain myocardial viability. In this connection it is

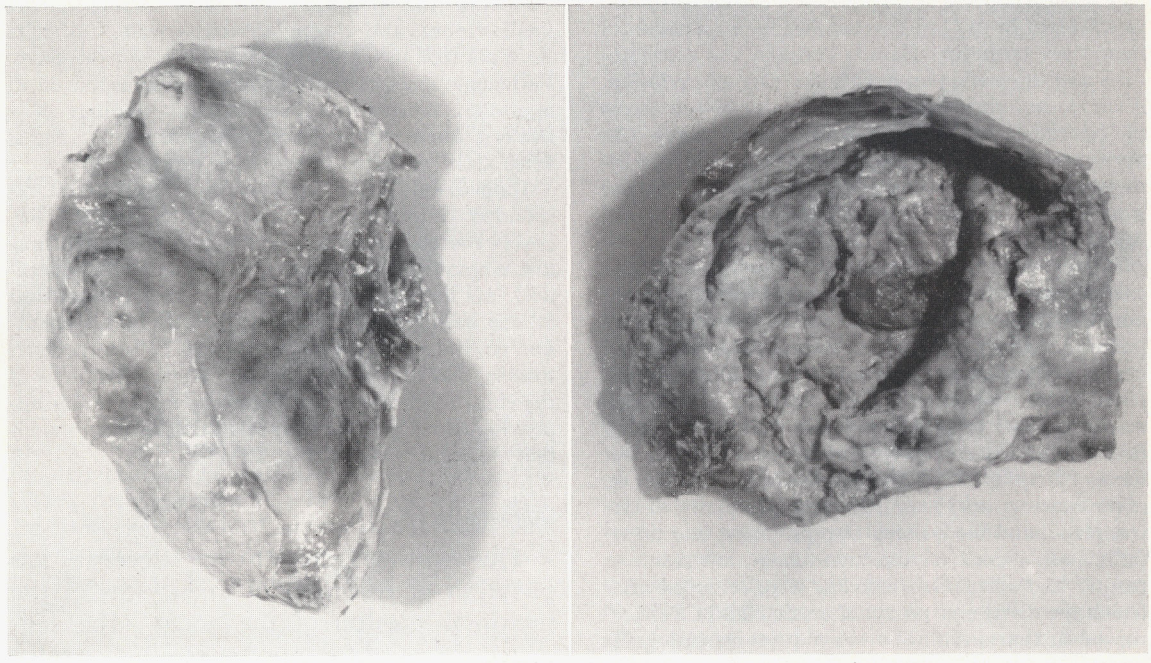

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FIG. 9. Photographs of: a, intact excised specimen showing fusiform aneurysm of ascending aorta and transverse arch, and, b, opened specimen showing degenerative changes in wall.

of interest to observe that in our first patient on whom this method was employed for resection of an aneurysm of the ascending aorta, cardiac arrest occurred about 10 minutes after occlusion of the aorta and persisted during the remaining 21 minutes required to complete the graft replacement. It was possible, however, to resuscitate the heart after release of the occluding clamp. It is believed that cardiac arrest occurred in this patient because it was necessary to apply the occluding clamp so far proximally on the ascending aorta that it obstructed the ostia of one or both coronary arteries. In the case herein reported the clamp could be applied above this level and cardiac function was maintained throughout the procedure.

In the clinical application of this method certain technical aspects of the procedure deserve consideration. In our early experience the approach employed consisted of anterior thoracotomy through the third interspace on both sides, with transection of the sternum and median extension of the incision cephalad to the supraclavicular notch and median sternotomy. In our more recent experience it has been found preferable to avoid the addition of the median sternotomy since adequate exposure can be obtained by bilateral thoracotomy through the third interspaces and this permits more stable closure of the chest wall. If the aneurysm extends so far into the superior mediastinal space as to interfere with proper exposure of the great vessels, it is preferable to expose the common carotid arteries by separate small incisions in the neck. In the dissection to free the aortic arch and aneurysm from surrounding structures, considerable care should be exercised to avoid injury to the innominate vein and pulmonary artery, which are often intimately adherent to the aneurysm. Under these circumstances, it may be preferable to abandon efforts to free these structures completely until after circulation through the aortic arch has been arrested. The aneurysm may then be safely entered, its contents evacuated, and its wall removed from surrounding structures by intramural dissection. The important step at this stage of the operation is to obtain complete circumferential mobilization of sufficient segments of the aortic arch proximal and distal to the aneurysm and of the great vessels arising from the arch to permit application of the occluding clamps.

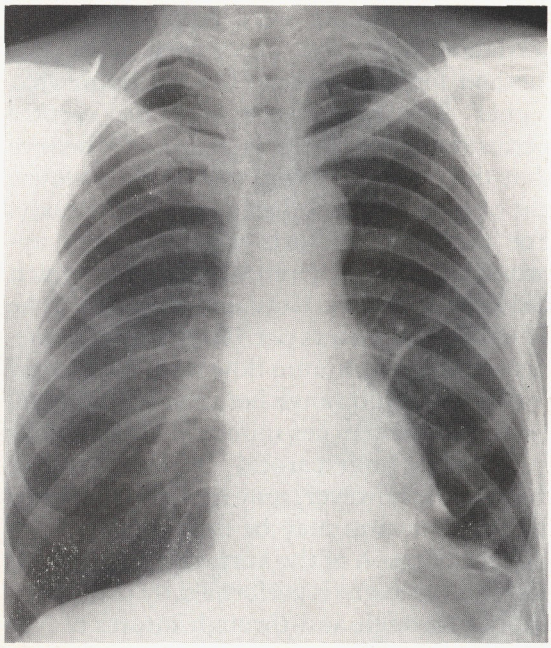

FIG. 10. Roentgenogram of chest made approximately 2 weeks after operation revealing absence of right mediastinal shadow representing aneurysm which was present in preoperative film shown in Figure 1.

Extracorporeal circulation is provided in the standard manner, with 3/16 inch plastic catheters inserted into the venae cavae to divert venous cardiac inflow into the artificial heart-lung apparatus from which oxygenated blood is returned to the patient through catheters inserted in the common femoral and both common carotid arteries (Fig. 4). Relatively small cannulas (No. 10 or 12 French polyvinyl plastic catheters) are used for the latter vessels in order to avoid obstruction to carotid circulation before perfusion with the pump-oxygenator is begun. By this means carotid circulation is maintained throughout the procedure. Relatively low flow rates of approximately 35 cubic centimeters per kilogram of body

weight per minute were employed in accordance with our experience with this method for intracardiac lesions. Somewhat higher flow rates were used for carotid perfusion, since there is reason to believe that the central nervous system is less tolerant of anoxia than other tissues of the body. For this reason efforts were made to approximate normal cerebral blood flow which has been found by Kety and Schmidt to be 54 cubic centimeters per 100 grams of tissue. Accordingly, optimum flow rates for carotid perfusion should range between 500 and 800 cubic centimeters per minute divided equally between both carotid arteries. Further experience, however, may indicate that even higher flow rates may be desirable.

After excision of the aortic arch lesion the graft replacement is performed by using continuous through-and-through sutures of No. 000 arterial silk for the anastomoses. It is preferable to perform the anastomosis of the graft to the distal end of the aortic arch first and then to the left common carotid and innominate arteries in that order with the final anastomosis to the ascending aorta since this method facilitates their technical performance. Under some circumstances, however, it may be desirable to perform the distal and proximal aortic anastomoses first after which the aortic clamps along with the vena caval occlusion could be released in order to restore normal cardiopulmonary function as rapidly as possible. The flow through the pump-oxygenator would then be reduced to the amount required to maintain carotid perfusion during the time required to complete the anastomoses to these vessels.

SUMMARY

The two major problems associated with resection of aneurysms of the proximal portion of the aortic arch are concerned with the rapidly fatal consequences of arrest of circulation through this vital segment of the aorta upon the heart and central nervous system. Earlier efforts to solve these problems were directed toward use of temporary shunts to provide circulation during excision and replacement of the diseased segment and use of hypothermia to reduce cardiac output and oxygen requirement by the tissue. Although these methods proved to be feasible and to some extent effective in overcoming these problems, they have certain disadvantages that impose additional risks to the operation. Moreover, in some cases in which, for example, the aneurysm arises quite proximally on the ascending aorta, it is not technically possible to make use of the shunt.

These disadvantages have been circumvented by use of temporary cardiopulmonary bypass with the artificial heart-lung apparatus. This method was first successfully employed about 1 year ago in a patient with an aneurysm involving the ascending aorta, which was resected and replaced with a homograft. Its successful application in a second patient reported herein with a fusiform aneurysm involving both the ascending aorta and transverse arch, treated by excision and homograft replacement including restoration of continuity to both the innominate and left common carotid arteries, would suggest that it provides a better method for the resection of fusiform aneurysms of the aortic arch.

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